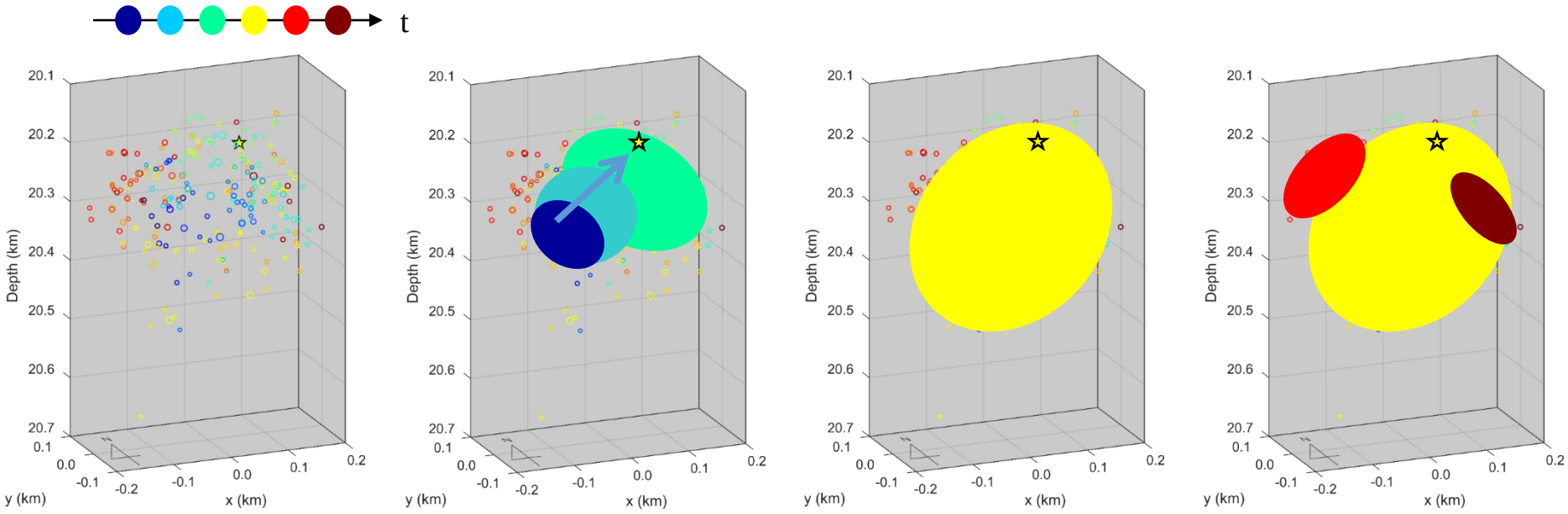
The 2020 Haenam earthquake sequence: the first observation of a seismic front migrating in a manner similar to fluid diffusion on the Korean Peninsula

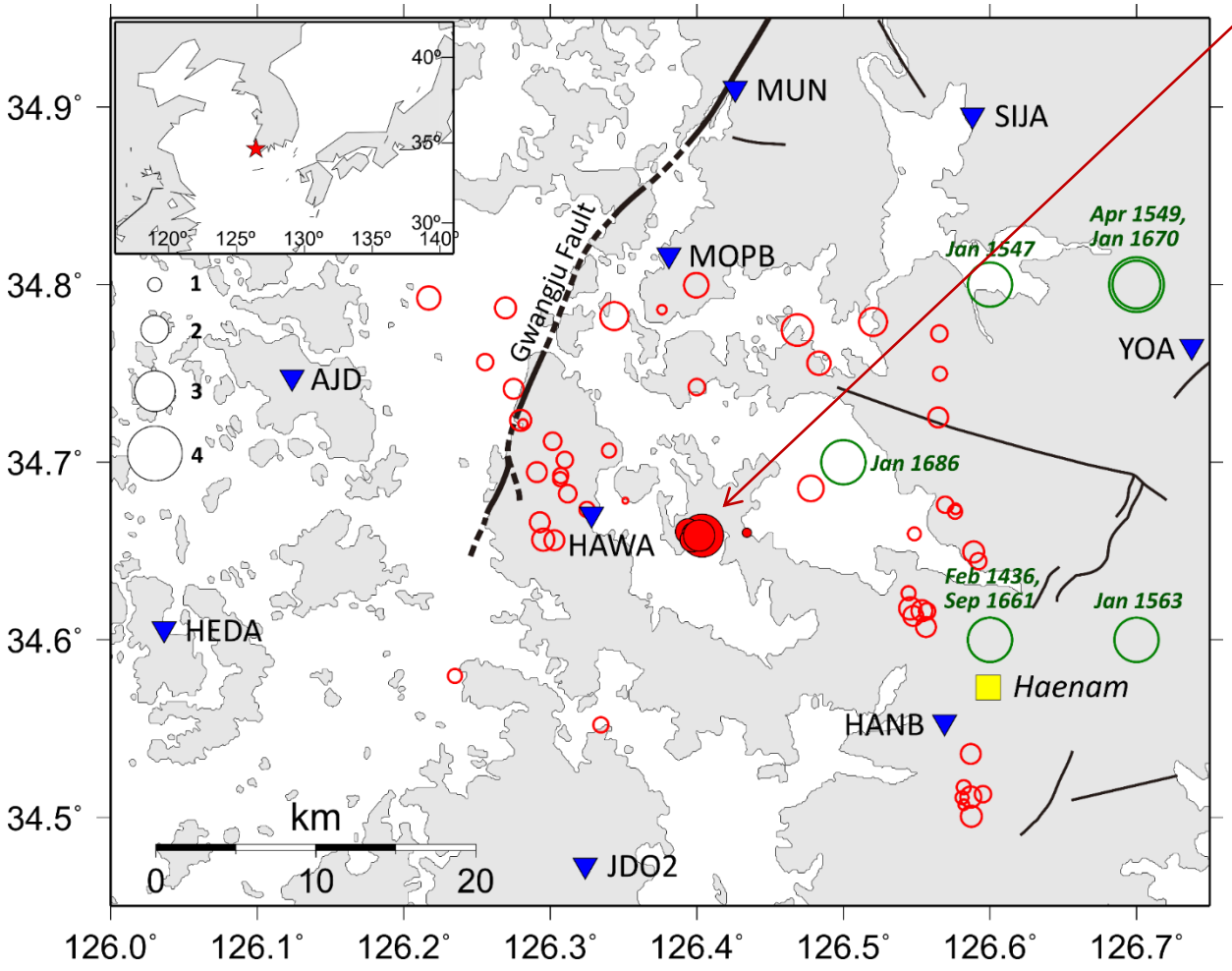
Minkyung Son (kersti@kigam.re.kr)[1*], Chang Soo Cho[1], Jin-Hyuck Choi[2], Jeong-Soo Jeon[1], and Yun Kyung Park[1]

[1]Earthquake Research Center, Korea Institute of Geoscience and Mineral Resources
[2]Center for Active Tectonics, Korea Institute of Geoscience and Mineral Resources



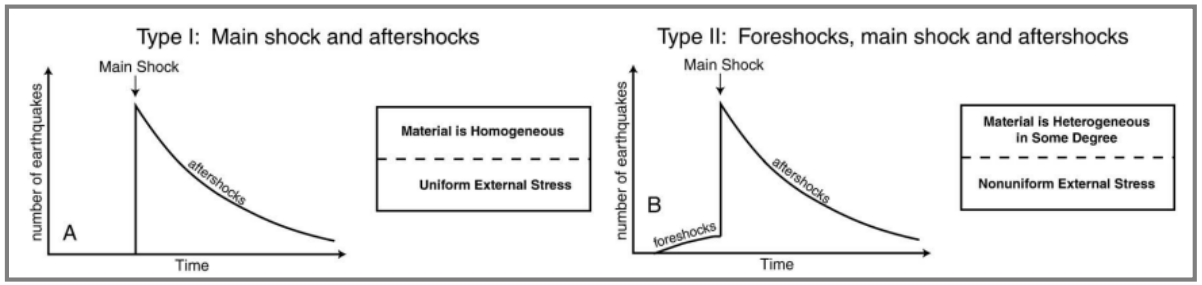
EGU General Assembly 2021

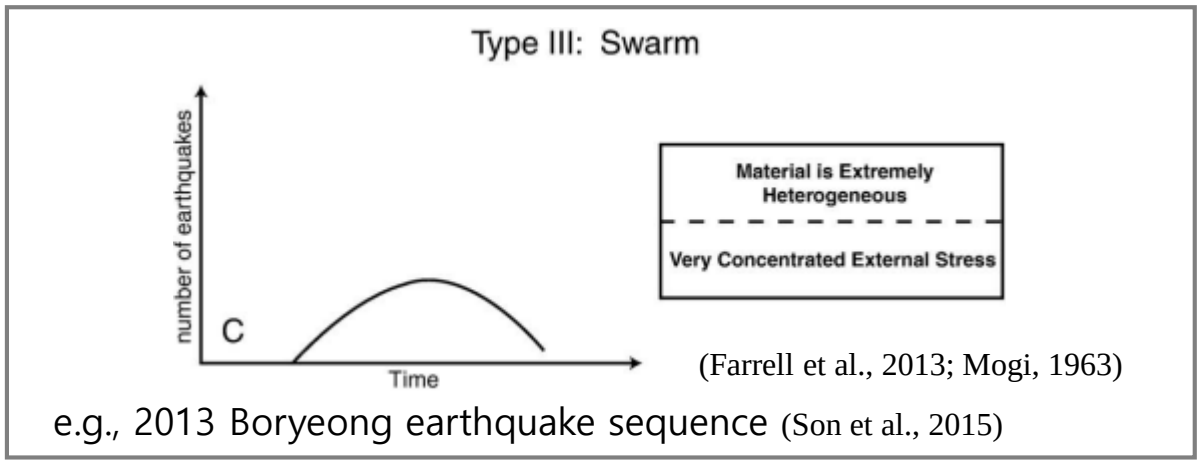
2020 Haenam earthquake sequence



2020 Haenam earthquake sequence

- from the end of April 2020
- the largest, 3.1 (M_L, KMA), May 3
- 71 events, 0.4–3.1 (M_L, KIGAM), April 26–May 8

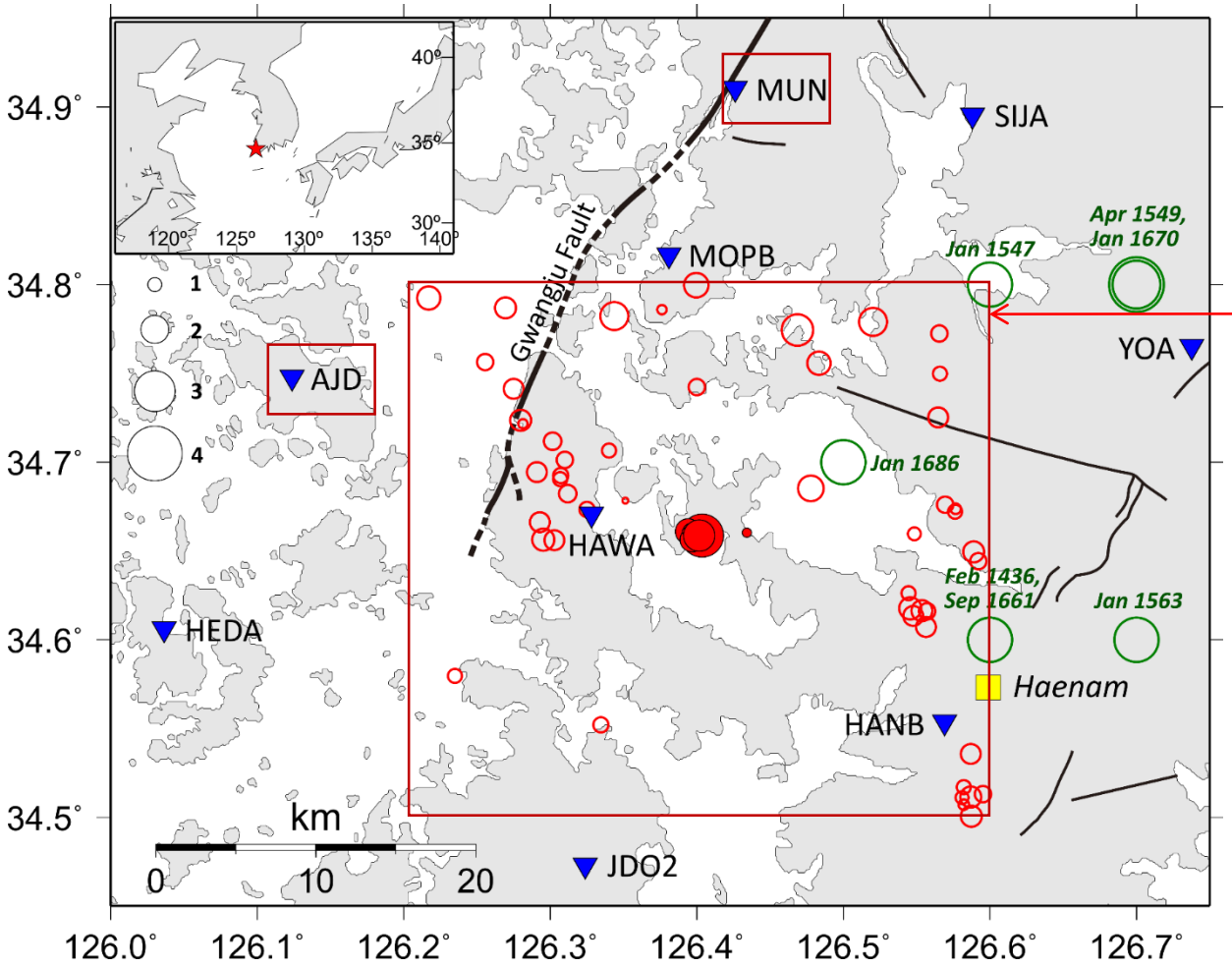




(Farrell et al., 2013; Mogi, 1963)

e.g., 2013 Boryeong earthquake sequence (Son et al., 2015)

Instrumental Seismicity



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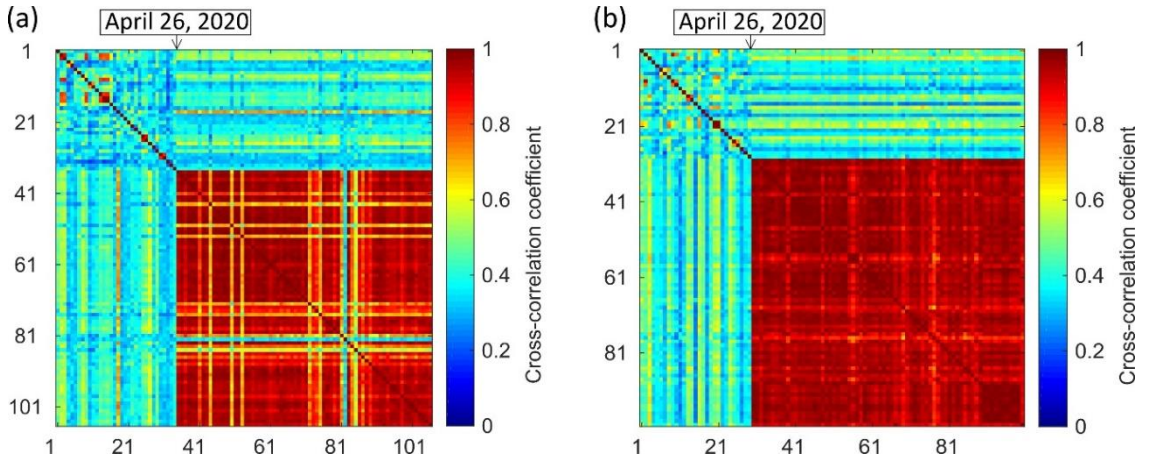
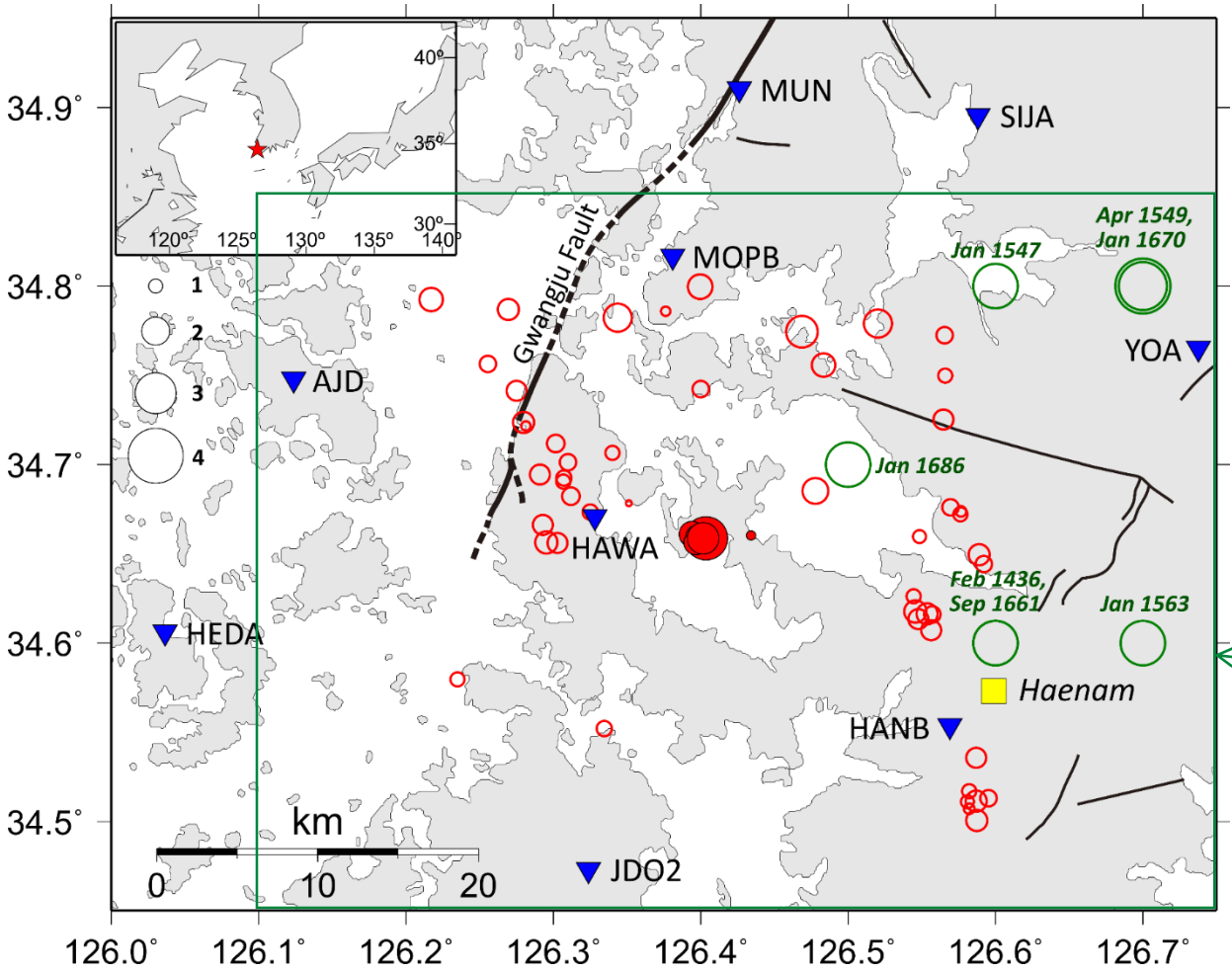
Instrumental seismicity
around the epicenter of the largest event

- November 2013–March 2020
- 50 events, 0.4–2.3 (M_L, KIGAM),



Historical Seismicity



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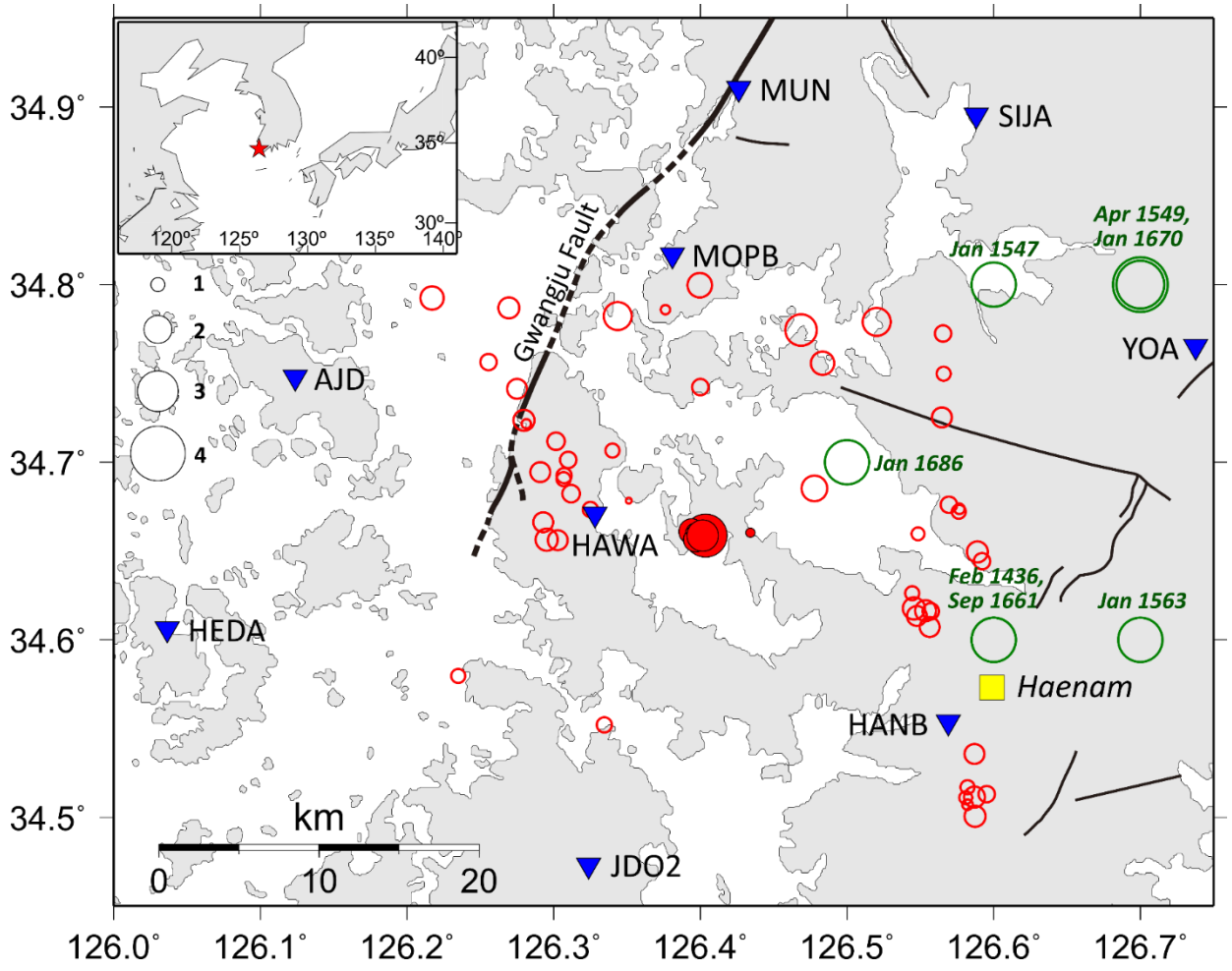
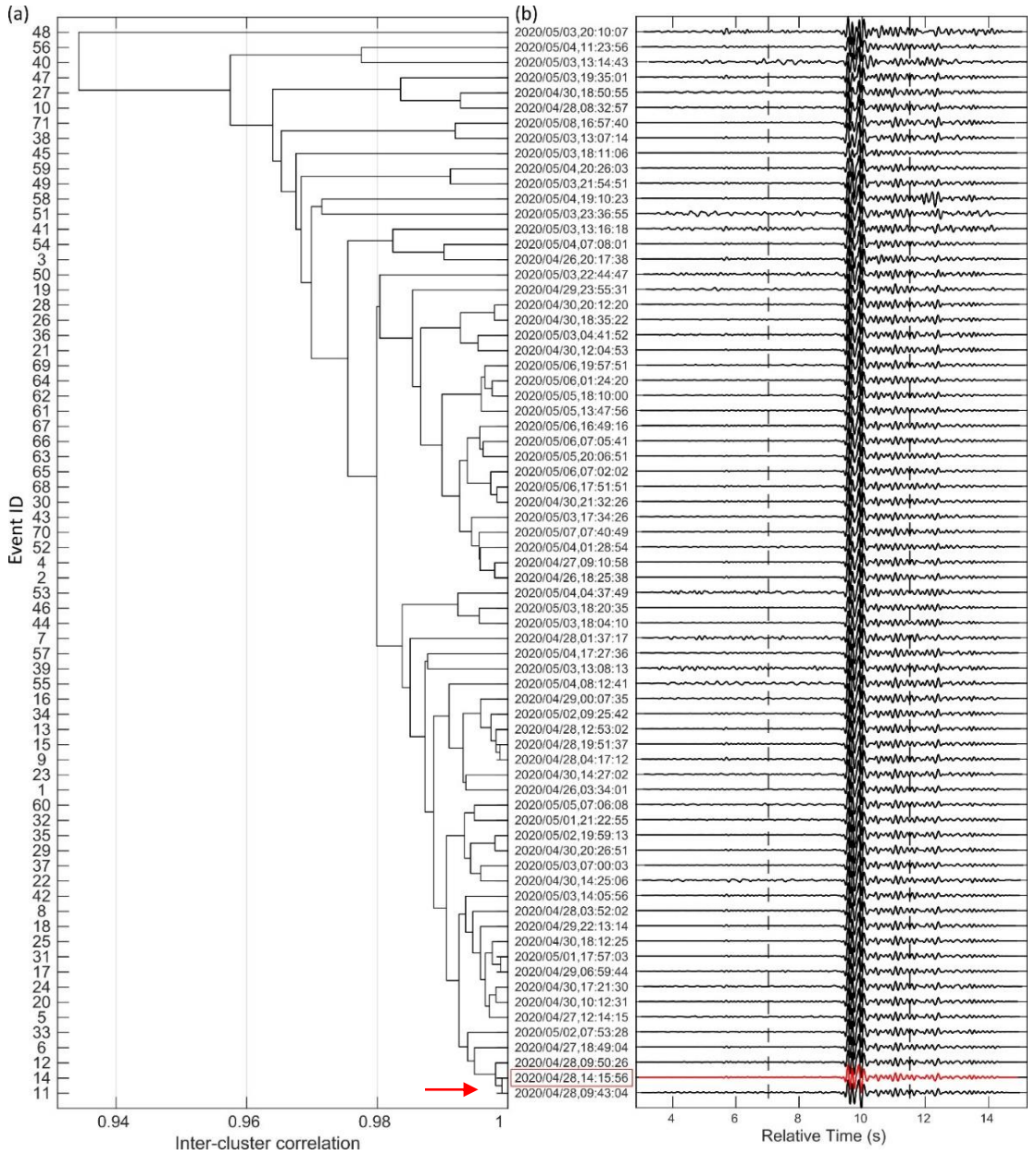
Historical earthquakes
around the epicenter of the largest event

- the middle period of Joseon dynasty
- 7 events, 3.2–4.0 (M; NEMA, 2012)

Waveform Classification for Master Event Determination





- 71 catalogued events / station AJD / 2–8Hz band-pass filter

Uncatalogued Event Detection Using Waveform Cross-Correlation

- Cross-correlation coefficients (CC) between continuous waveform and the master record

- Seven years (March 7, 2013 to May 11, 2020)
- Master event (UTC 2020/04/28, 14:15:56)

▮ April 25, 2020 to May 08, 2020

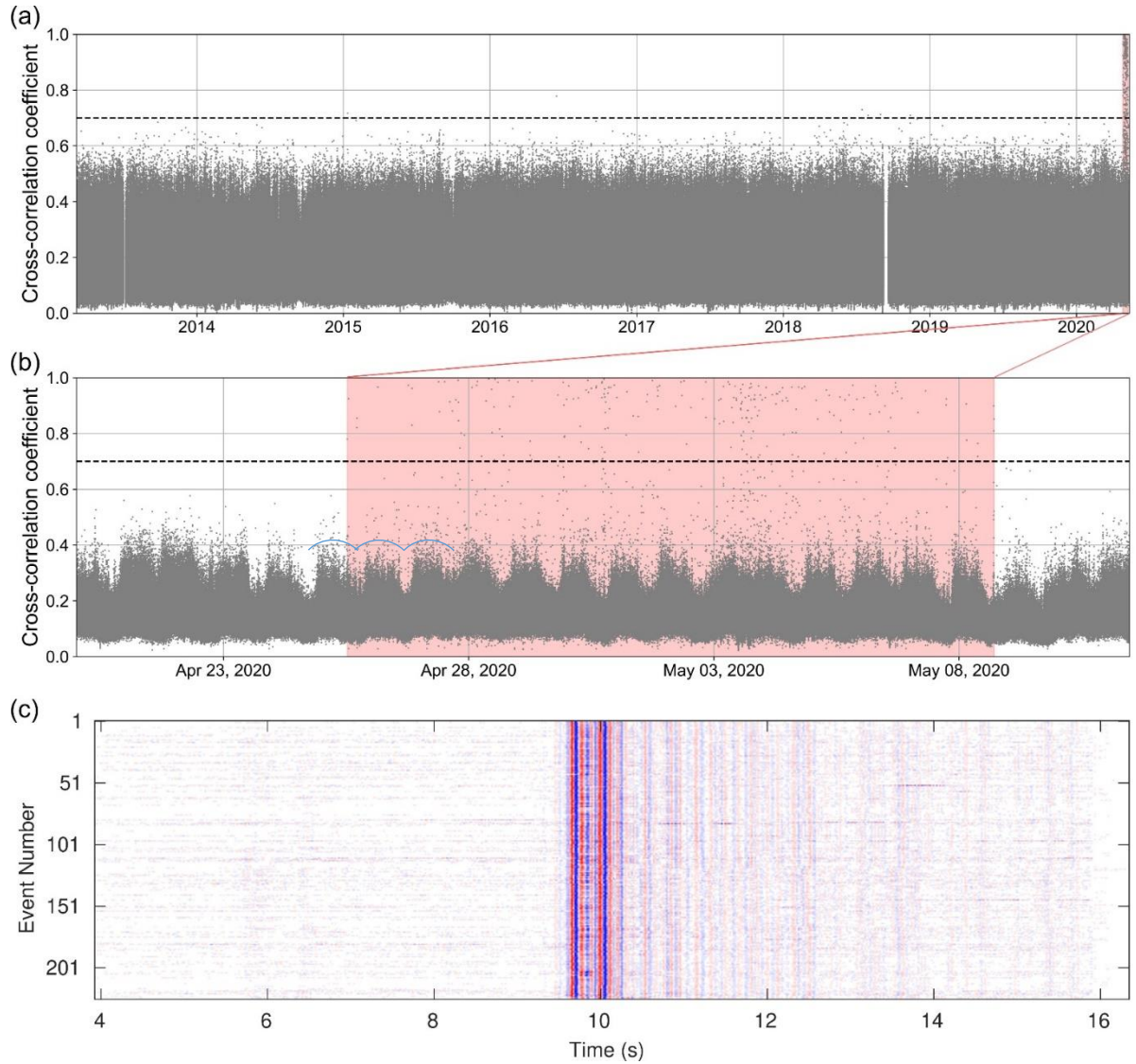
--- CC = 0.7

⇨ Newly identified 155 events

⌒ Day-night cycle in seismic noise

Waveform similarity

indicating hypocenters in close proximity



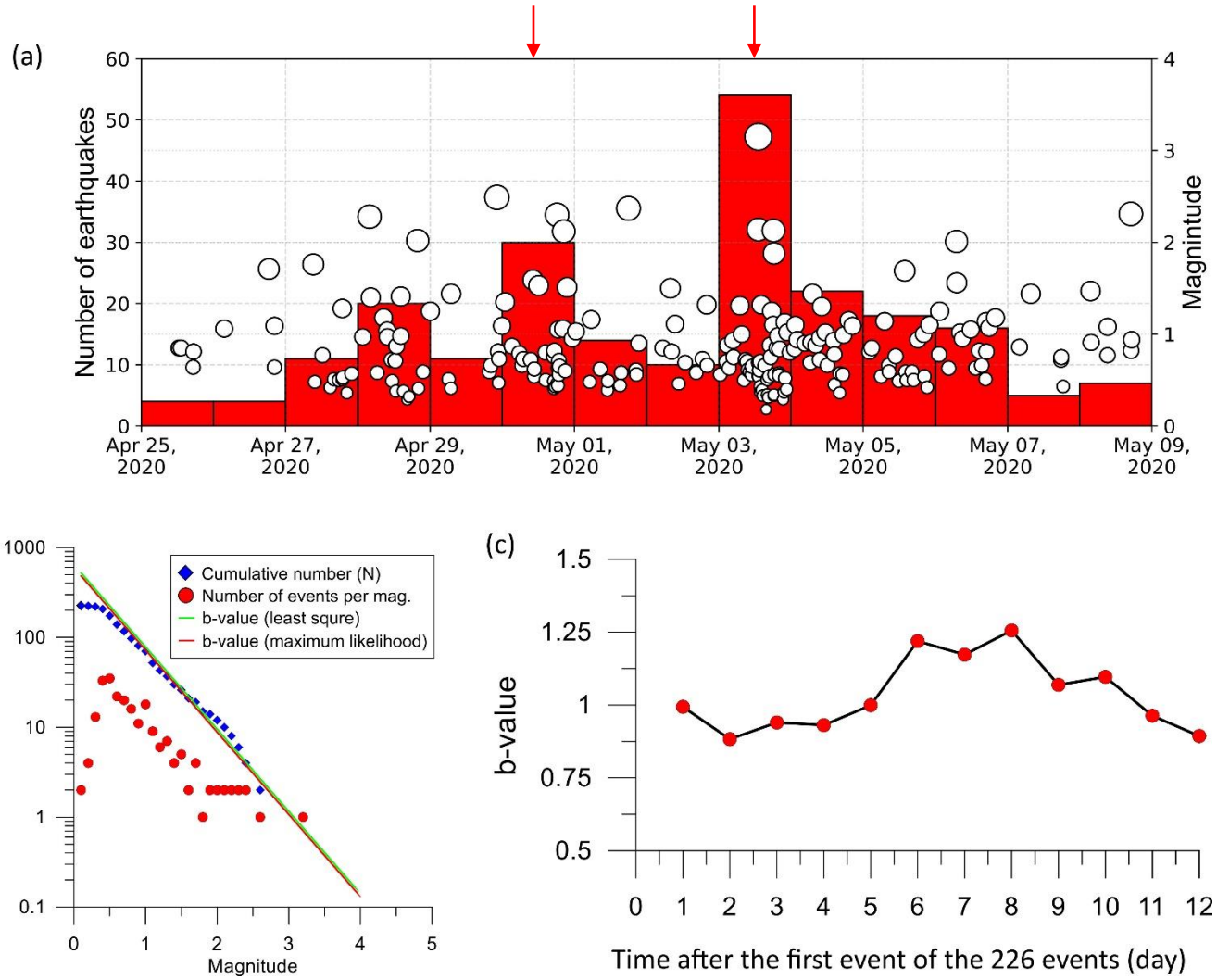
Temporal Distribution and Magnitude Distribution

April 30, 2020 / (decline phase) / May 3, 2020

b-value, 0.92 (M_c 0.5)
- typical for mainshock-aftershock sequences in tectonic environments
  (e.g., Kagan, 1997; Schorlemmer et al., 2005)

Temporal changes in b-values
- b-value, ~1.2 for the period around the mainshock occurrence

b-values, not sufficient diagnostic criteria for an earthquake swarm
(Hainzl and Fisher, 2002; Hill et al., 2003; Gulia et al., 2018)

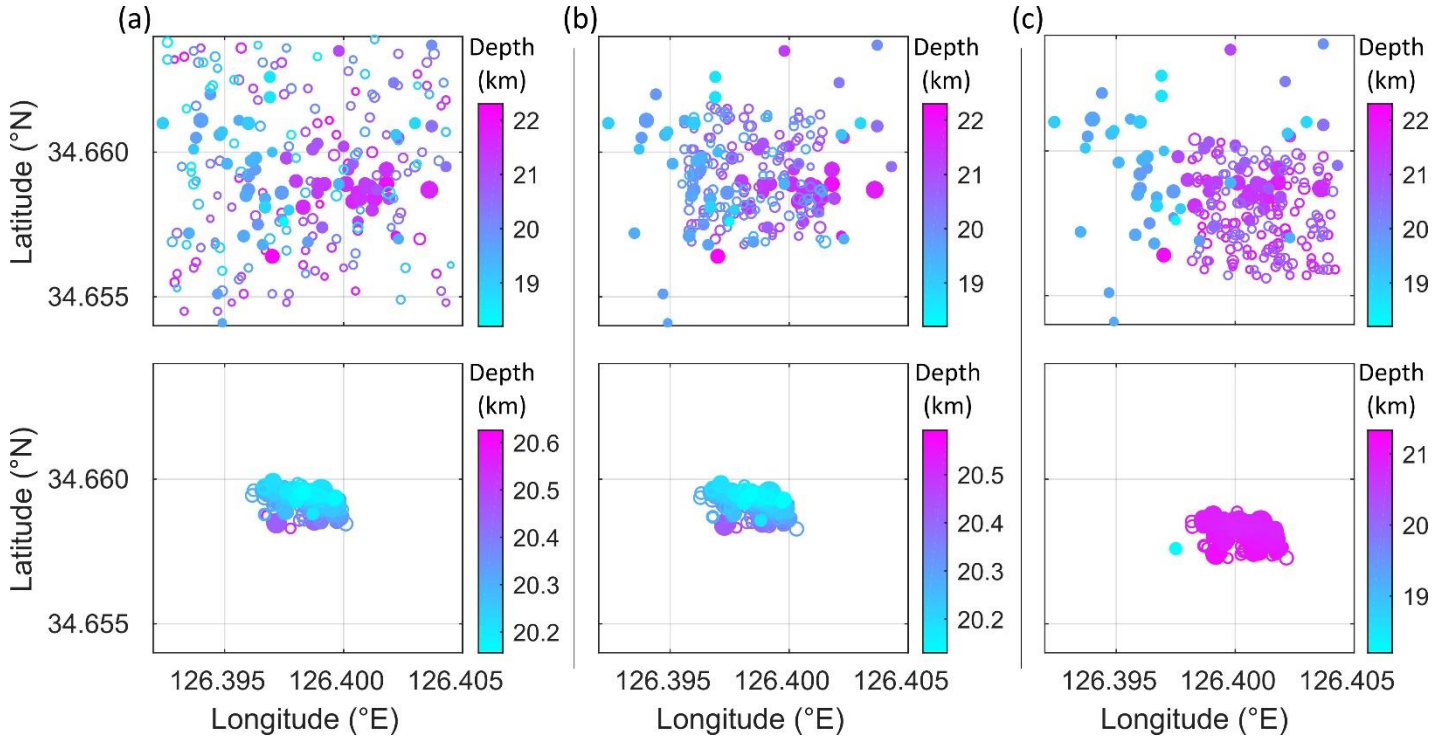


Hypocenter Relocation

- Assign initial location to uncatalogued 155 events,
  by random perturbation with the averaged hypocenter of the catalogued events
  (based on the relocation of the 2013 Baekryeong earthquake sequence (Son et al., 2015))

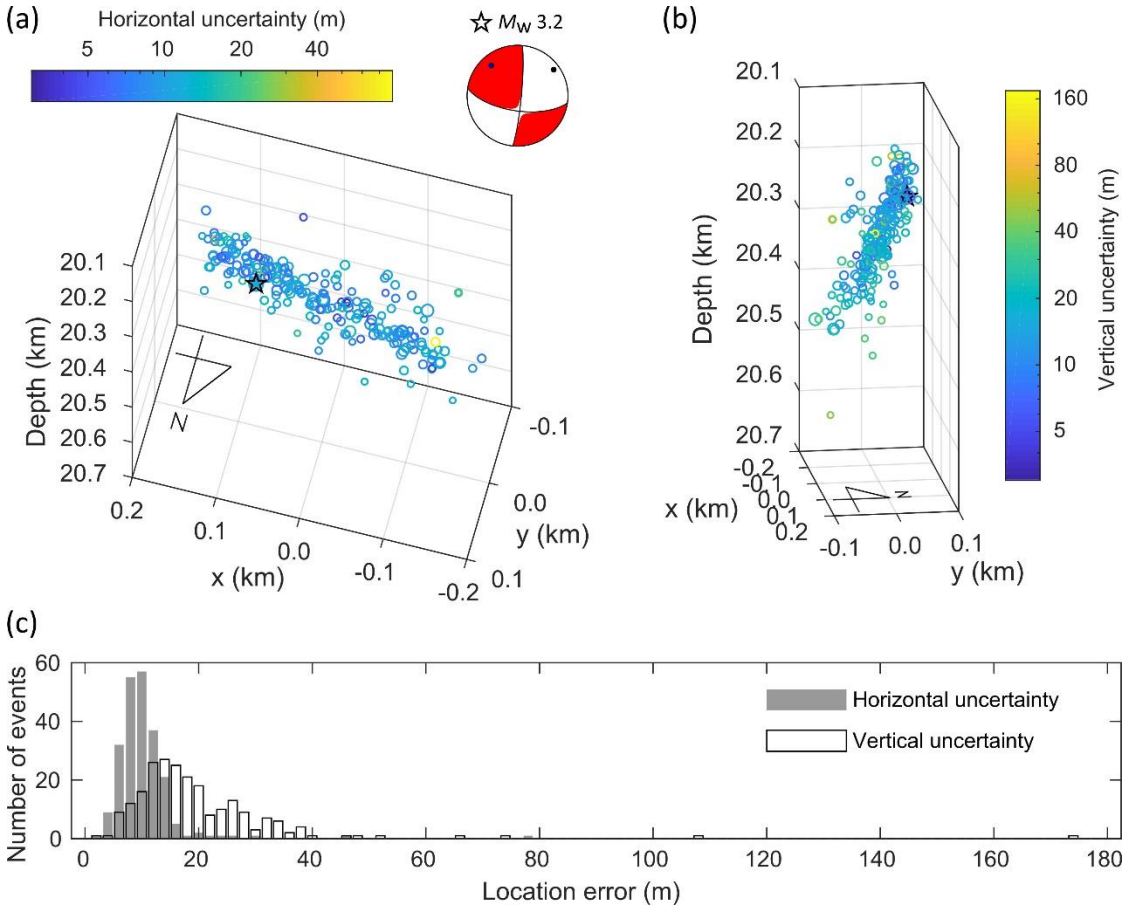
- Relative earthquake relocation based on double-difference technique and hierarchical clustering of waveforms

  (Trugman and Shearer, 2017; Rubinstein et al., 2018;
  Ross et al., 2020; Hatch et al., 2020)



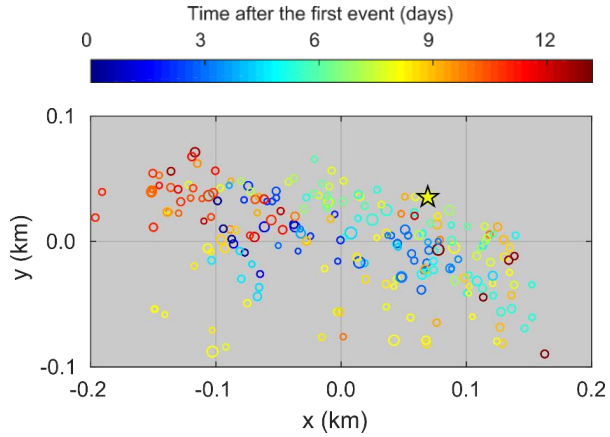
Clear Lineament of Relocated Hypocenters

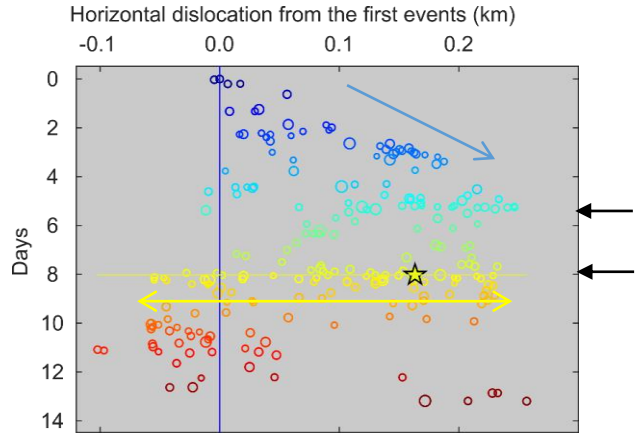
- Clear lineament, WNW-ESE
- Deepening SSW
- Meter scale error

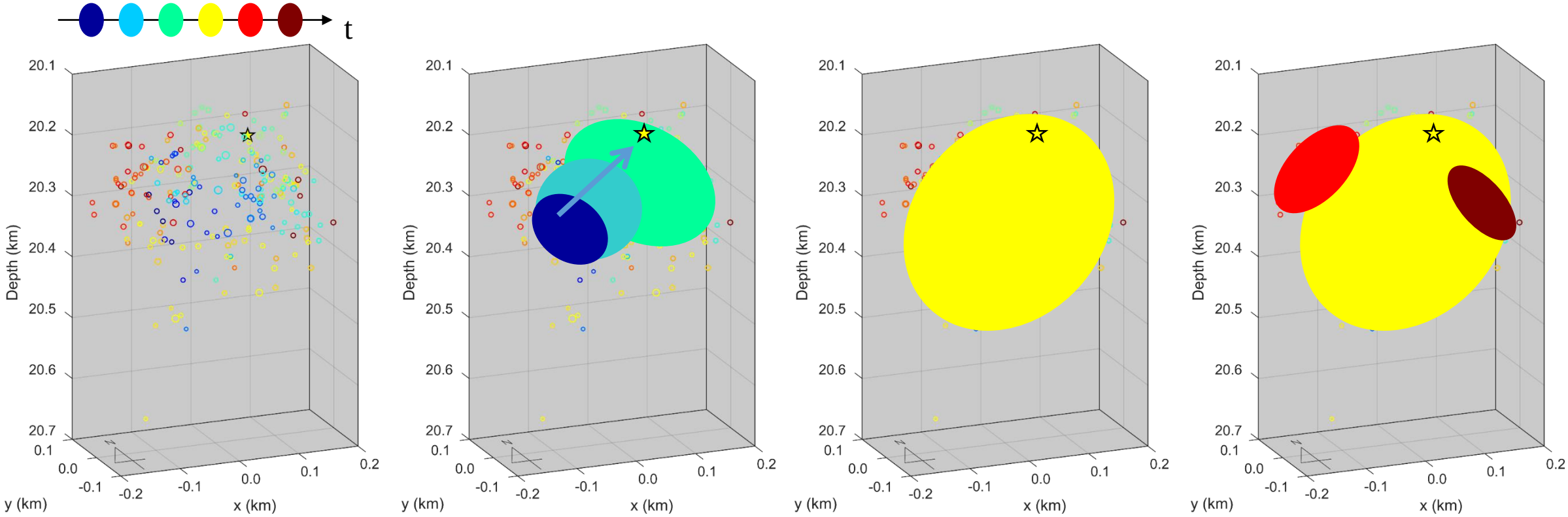


Hypocenter Migration

- Spatiotemporal evolution of seismicity:
  progression toward the upper east /
  the largest event rupturing /
  the final parts on both ends of the fault







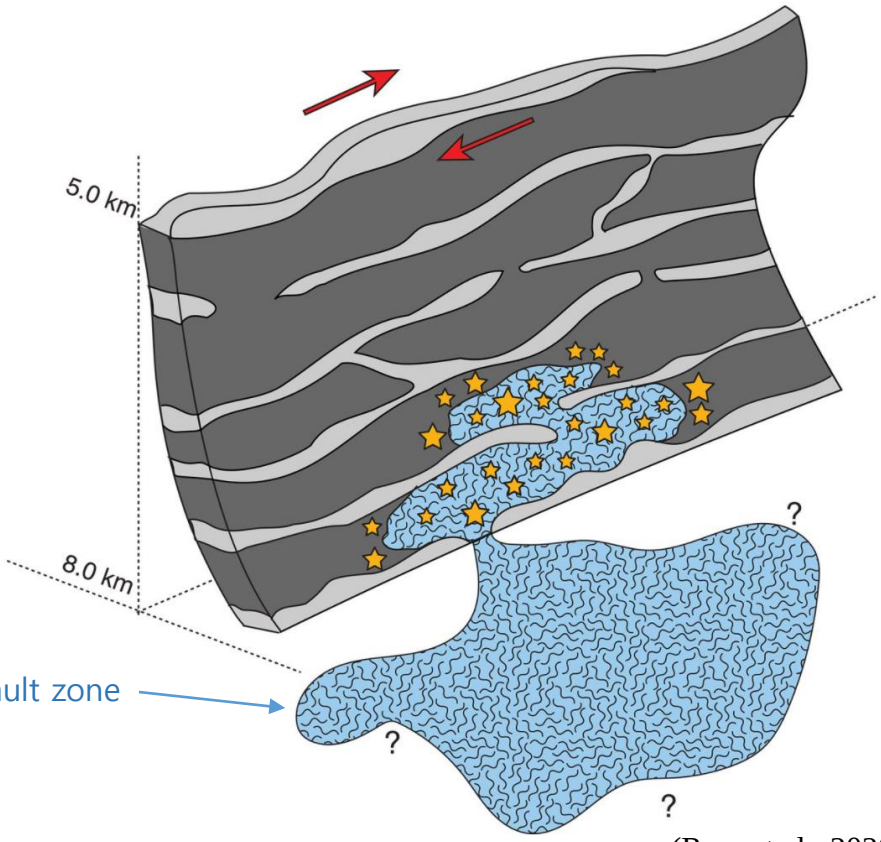
- Fault-valve behavior? / Successive rupture growth?

Driving Forces of Migrating Earthquake Swarms

Magmatic events (before and during volcanic eruptions)

Aseismic slip (fault creep)
- no major fault accommodating tectonic stress,
- no reports on geodetic deformation and surface faulting,
- 0.04 km/day << references (e.g., Lohman and McGuire, 2007)

Spreading fluid or hydrothermal circulation
(e.g., West Bohemia/Vogtland – an intraplate region;
Yellowstone Lake;
Cauhilla Valley, California;
Mammoth Moutain;
Sierra Nevada range south of Long Valley Caldera;
and fluid injection experiments)



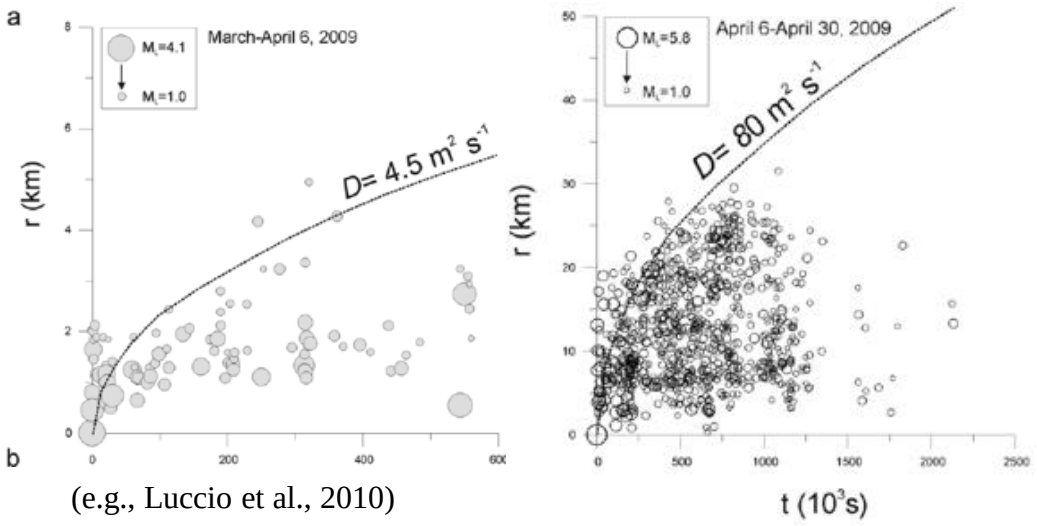
(Ross et al., 2020)

Hypocenter Migration and Fluid-faulting Interactions

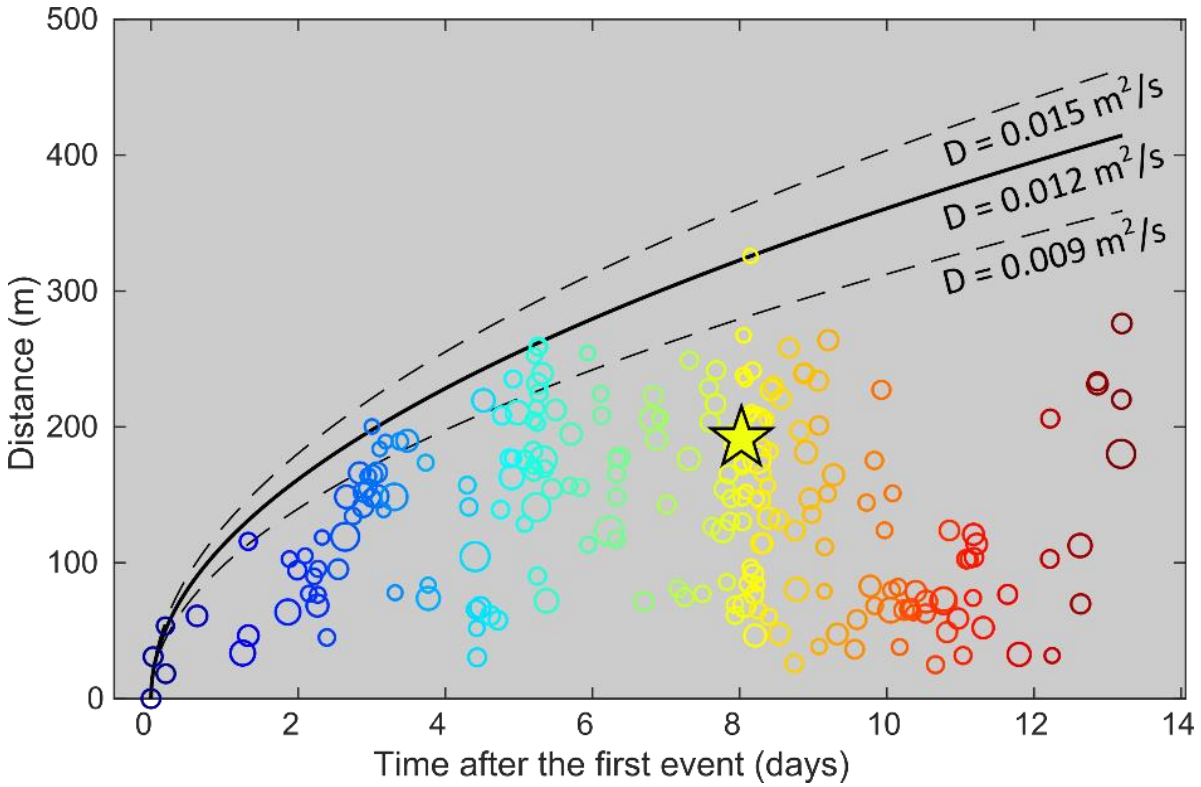
* Fluids are often involved in swarm-like sequences!
(e.g., Hill, 1977; Shapiro et al., 1997; Schapiro et al., 2002; Hainzl, 2004; Chen and Shearer, 2011; Shelly et al., 2015; Ross et al., 2020)

Fluid pressure diffusion (the spreading of the fluid flow)

$$r = \sqrt{4\pi D t}$$ (Shapiro et al., 1997)



(e.g., Luccio et al., 2010)



Fluid-driven Earthquake Swarm?

* Reduction in frictional strength due to fluid diffusion

Shown in our study …

Seismic migration front matching the fluid diffusion curve

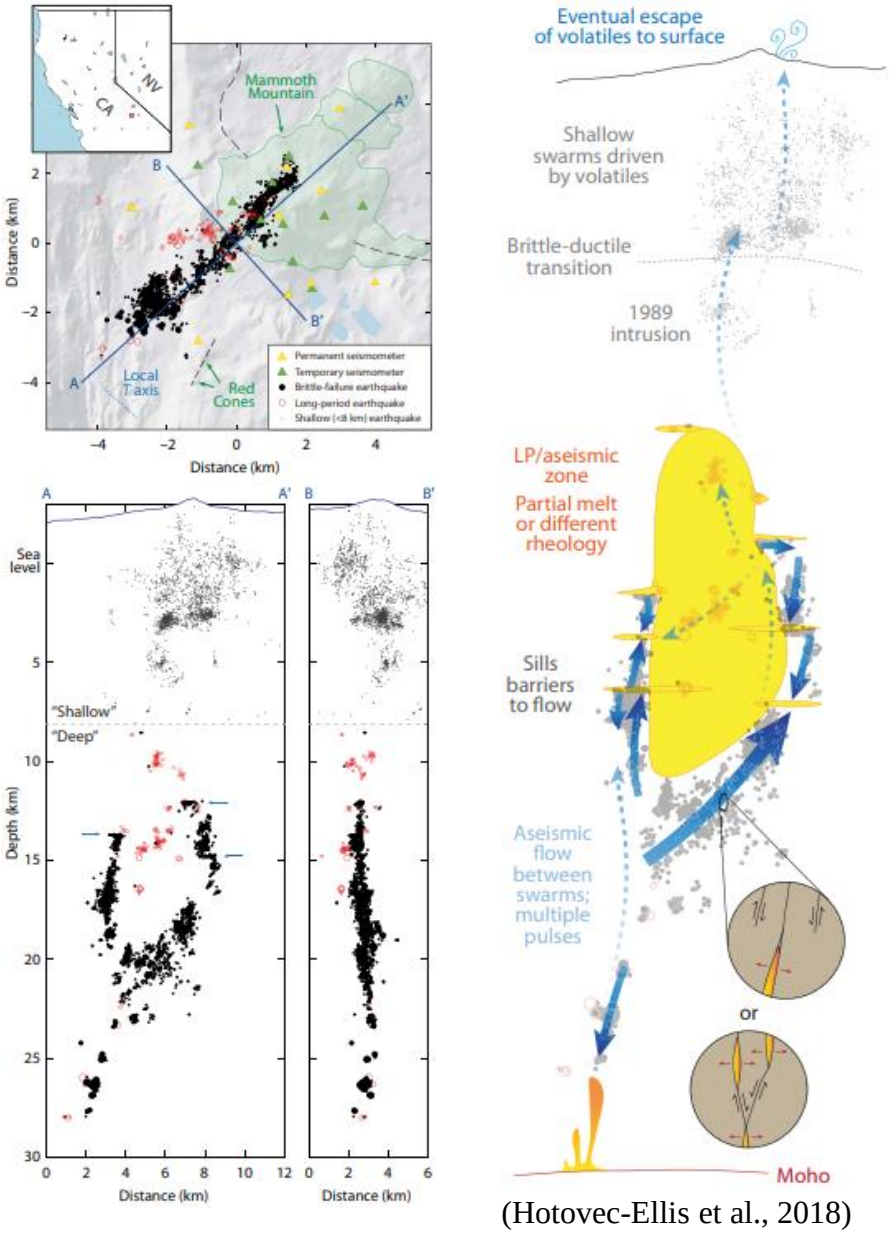
Geological environments: Possible fault-mesh structure?
- WNW-ESE trending fault set without a major fault, intensive fractures and/or veins around each fault

(Koh and Chang, 1997; Yang et al., 2013; Ryoo et al., 2014)

Q. Fluid below ~20 km depth?
- fluid pressure pulses associated with CO_2 exsolution (Mammoth Mountain, California) (Hotovec-Ellis et al., 2018)

Q. CO_2 exsolution?
- Intra-continental earthquake swarms in West Bohemia and Vogtland (hypocenter depths, 6 ~ 13 km) (Fischer et al., 2014)

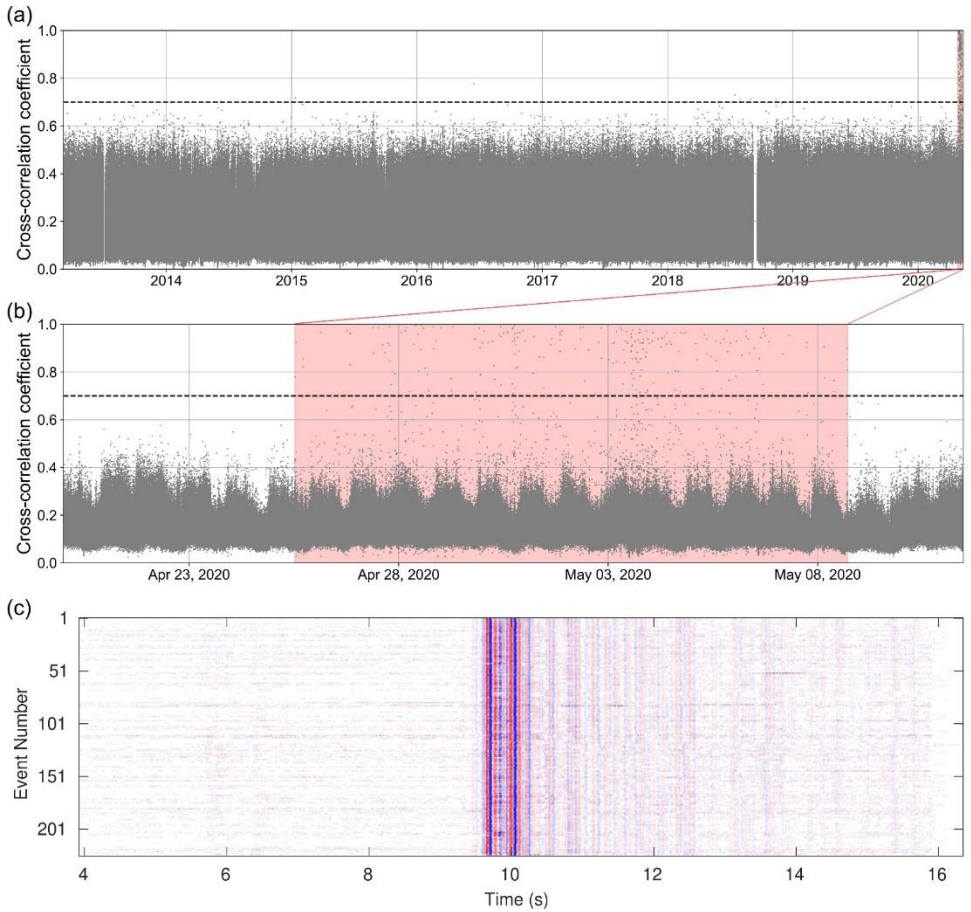
As the Korean Peninsula …



(Hotovec-Ellis et al., 2018)

Conclusions

- Waveform cross-correlation with seven-year-long continuous data
- The sequence starting on April 25, 2020 (one day before the first catalogued event occurrence)



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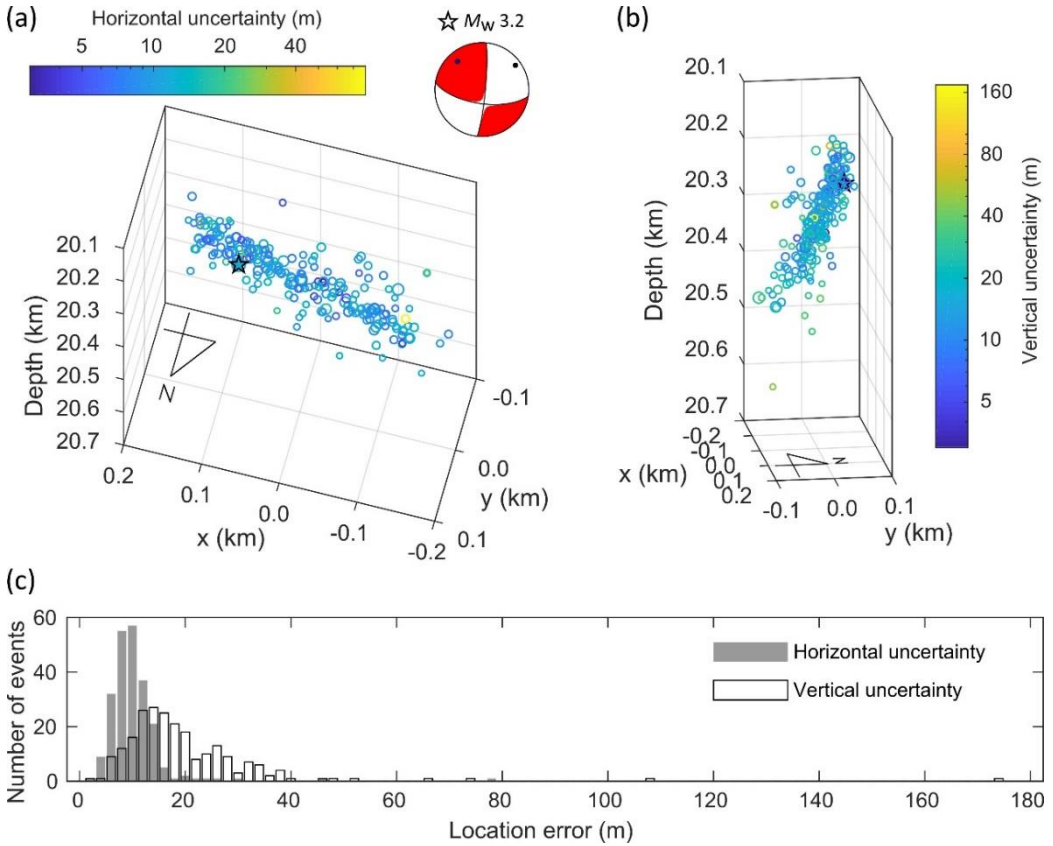
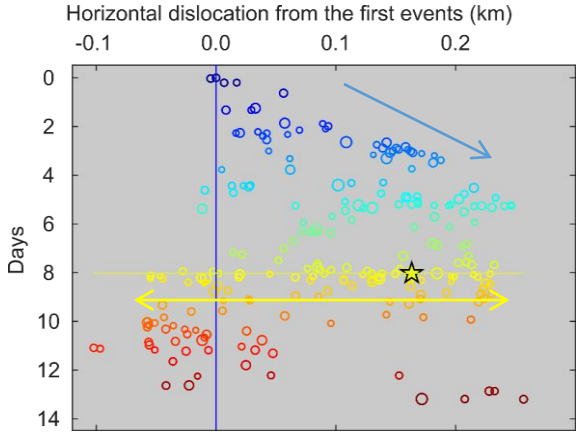
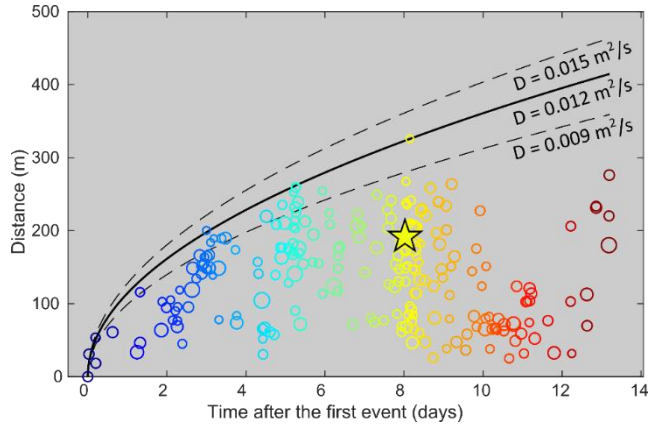


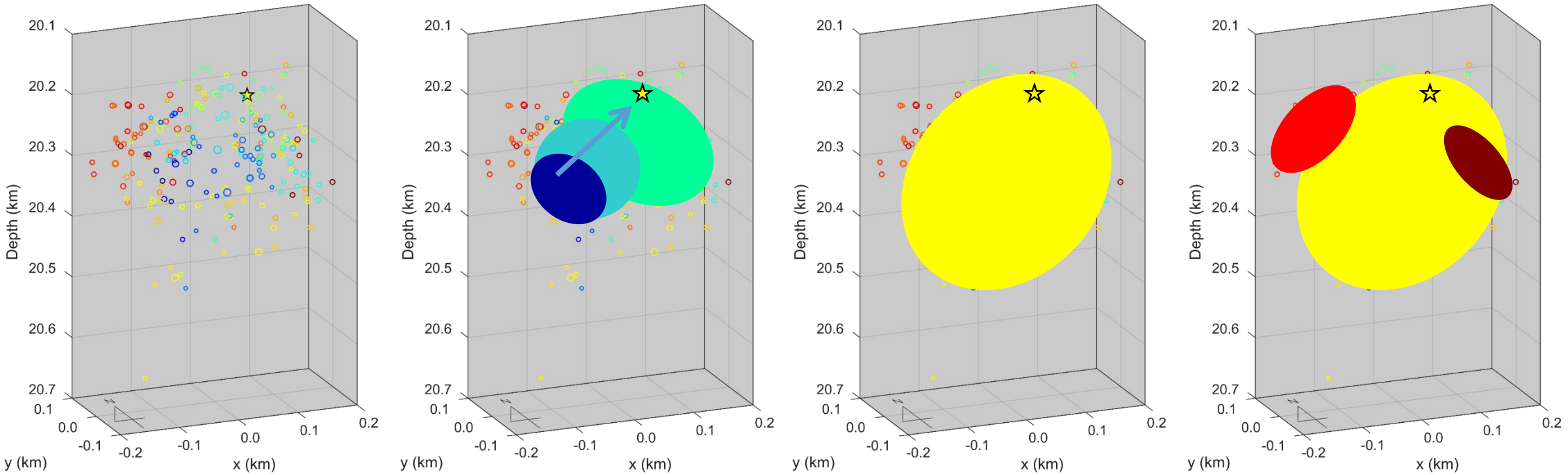
Conclusions

Observation of
- spatiotemporal evolution of the seismicity
- migration front, comparable to
  the spreading of the fluid flow





Possible fluid-driven earthquake swarm on the fault-mesh structure



THANK YOU

Contact me:
kersti@kigam.re.kr

Please see also,

Son, M. et al. (2021). Spatiotemporal patterns of the 2020 Haenam earthquake sequence, South Korea: lineament and migration implying fluid-driven earthquake swarm. Geosciences Journal.

Son, M. et al., (2020). Partitioned fault movement and aftershock triggering: Evidence for fault interactions during the 2017 Mw 5.4 Pohang Earthquake, South Korea. JGR: Solid Earth